Spatial and temporal variability of modeled and remotely sensed soil moisture products

K. Rötzer, C. Montzka, and H. Vereecken*
Forschungszentrum Jülich GmbH, Agrosphere (IBG 3),
Jülich, GERMANY
*k.roetzer@fz-juelich.de

JÜLICH FORSCHUNGSZENTRUM

Introduction

Hydrological and climate models as well as numerical weather prediction models require information about soil moisture and its spatio-temporal dynamics. A good way to provide global soil moisture data is through remote sensing. This method, however, has limitations because spatial or temporal resolution are not always sufficient for application. A possibility therefore is to match products from different sensors. This requires knowledge about the spatial and temporal characteristics of these products.

This study compares spatial and temporal variability of 3-day-composites of global SMOS- and ASCAT soil moisture products for the years 2010 – 2012 to the modeled ERA Interim soil moisture product. Based on USDA soil orders, correlation of ranks of mean relative differences (MRDs) are investigated and the relationships of spatial mean and spatial variance are examined for selected areas. Factors influencing the soil moisture distribution are analyzed.

Methods

- SMOS- and ASCAT products are averaged to ERA Interim Grid for comparison
- Analysis of spatio-temporal soil moisture variations through the relation between spatial mean $\bar{\theta}_t$ and spatial variance σ_t^2 of every soil moisture value for pixel n at time t

$$\bar{\theta}_t = \frac{1}{N}\sum_{n=1}^{N}\theta_{nt} \qquad (1)$$

and

$$\sigma_t^2 = \frac{1}{N}\sum_{n=1}^{N}\left(\theta_{nt} - \bar{\theta}_t\right)^2 \qquad (2)$$

- Mean relative difference $\bar{\delta}_n$ is calculated for every pixel through

$$\bar{\delta}_n = \frac{1}{T}\sum_{t=1}^{T}\frac{\theta_{nt} - \bar{\theta}_t}{\bar{\theta}_t} \qquad (3)$$

- MRDs are ranked from lowest to highest and these ranks are compared for the different products through correlation analysis

Acknowledgements: The authors thank ESA for providing the SMOS soil moisture product, Eumetsat for the ASCAT soil moisture product, ECMWF for the ERA Interim soil moisture and ISMN for the in situ data

Data

SMOS (Soil moisture and ocean salinity)
- Volumetric soil water content [m³/m³]
- SMOS Level 2 Processor Version 5.01

ASCAT (Advanced scatterometer)
- Relative soil moisture [%]
- Conversion into absolute soil moisture with ISRIC data
- SOMO version 2.0 (from 18/08/2011: version 3.1)

ERA Interim
- Model reanalysis from ECMWF
- Volumetric soil water content [m³/m³] of Layer 1 (0-5cm)

In situ data
- Provided by International Soil Moisture Network (ISMN)
- Example regions:
  → Aridisols in western USA, in situ data from SNOTEL network
  → Ultisols in southeast USA, in situ data from SCAN network
  → Andisols in southeast Australia, in situ data from OZNET network

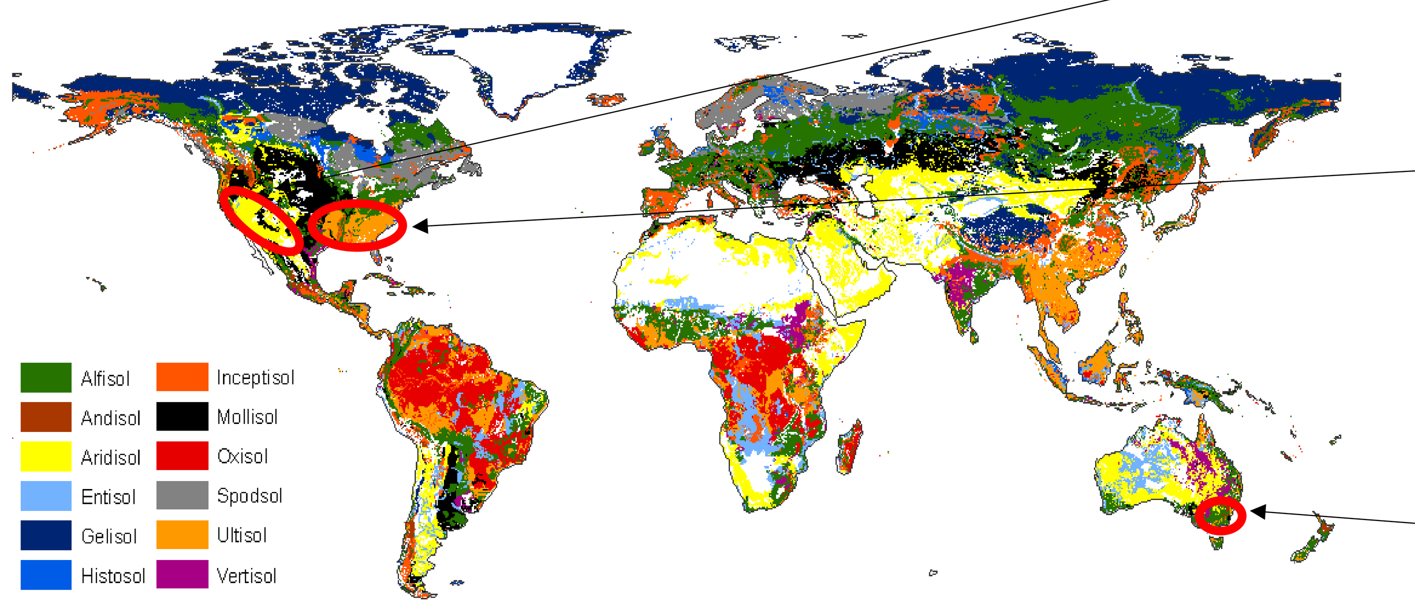


Fig. 1: USDA soil orders and example areas

Temporal mean of soil moisture

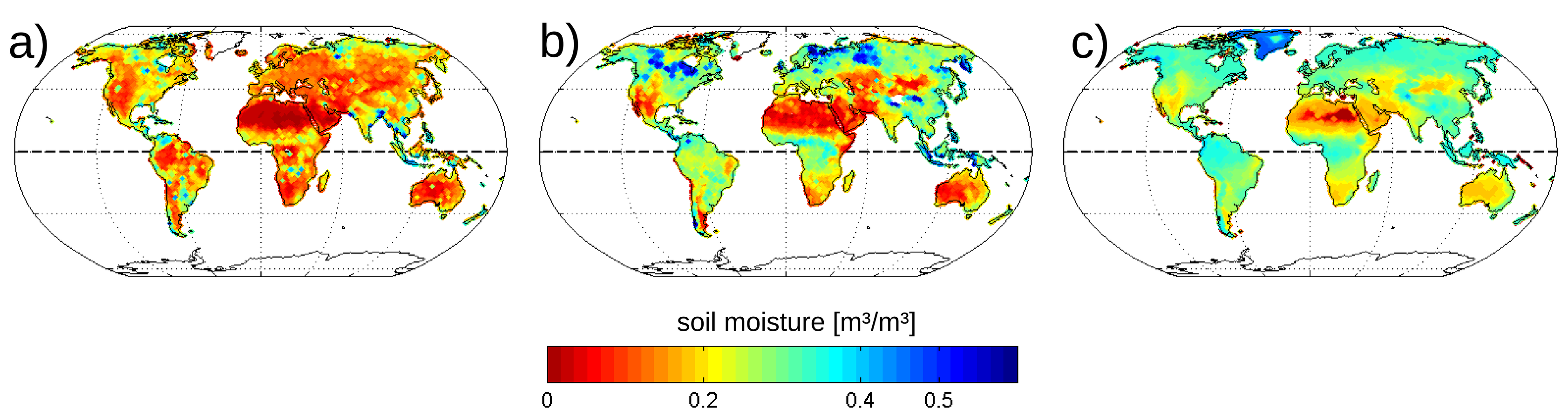
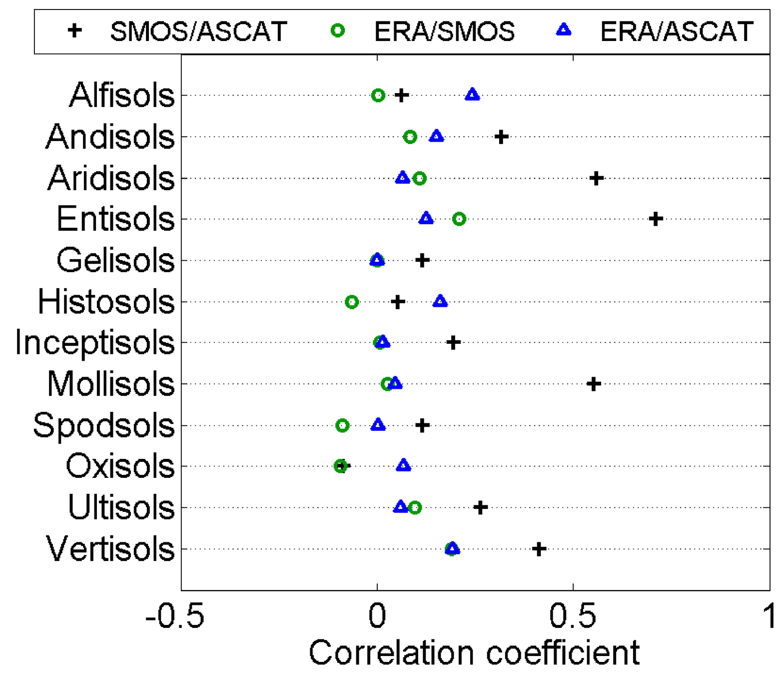


Fig. 2: Spatial distribution of temporal means for a) SMOS, b) ASCAT, and c) ERA Interim soil moisture. The overall distribution is similar for all products, while the ranges of values vary considerably. SMOS shows relatively low soil moisture values, wheras for ASCAT the range of values is dependent on the data used for conversion to absolute soil moisture. In contrast, for ERA few extremes are seen. Even after averaging, the remotely sensed products exhibit a much larger range of values than ERA. In general, the patterns are very similar: Some areas exhibit problems in the soil moisture retrieval for a specific product: Tropical rainforests, for example, exhibit very small values in the SMOS product.

Correlation of mean relative differences

Fig. 3: The correlations of MRD ranks between the different soil moisture products give information about the similarity of their spatial and temporal variability, as similar rankings of MRDs indicates similar soil moisture distributions: SMOS and ASCAT show highest similarities for most soil orders. Higher correlations also indicate more precise retrieval, here for soils with low vegetation like Aridisols or Mollisols.



Spatial mean and variance

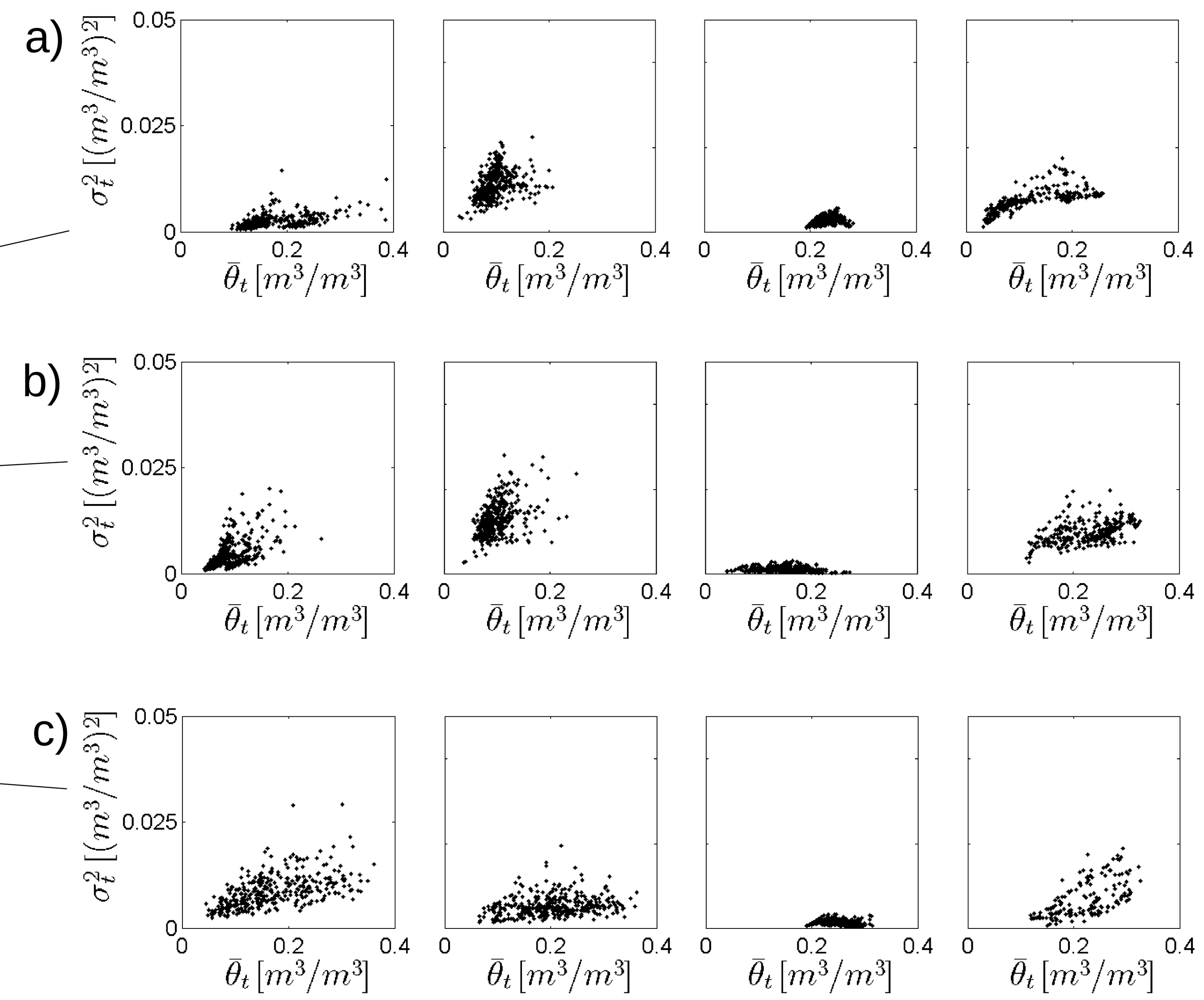


Fig. 4: Correlation of spatial mean and spatial variance of soil moisture for a) Aridisols in western USA, b) Ultisols in southeast USA and c) Alfisols in southeast Australia. Left side shows SMOS, middle left ASCAT, middle right ERA Interim and right the in situ soil moisture. The ranges of mean values and variances of the products are similar, except for the ERA product, which shows a small range of mean soil moisture values and very low varibility. Different sensor and retrieval characteristics influence the shape of the relationships of the different products. The SMOS product shows a positive linear relationship for all areas, ERA exhibits a convex shape, while ASCAT and in situ soil mositure show different relationships for the different regions.

Conclusions

- All products show a similar overall soil moisture distribution, deviances in specific areas indicate retrieval issues for a product in these conditions.
- The correlation of the mean relative differences shows the highest similarities between SMOS and ASCAT for most of the soil orders. Correlations of ERA with SMOS are generally low.
- All soil moisture products show different relationships of spatial mean and spatial variance. ERA Interim exhibits only a small range of values and a very low spatial variance.
- Although the soil moisture products generally show similar soil moisture patterns, their spatial and temporal characteristics are different.
- Prior to the use of different soil moisture products in one application, the examination of the spation-temporal characteristics for every individual region is crucial.